TT 30: Caloric Effects in Ferromagnetic Materials (joint session MA/TT)

Time: Tuesday 9:30–11:30 Location: POT/0151

Invited Talk TT 30.1 Tue 9:30 POT/0151

Magnetic Cooling: From applications at room temperature to hydrogen liquefaction — •T. Gottschall[1], E. Bykov[1], M. Strassheim[1], T. Platte[2], C. Fujta[2], D. Benke[2], M. Fries[2], W. Liu[3], A. Döring[3], K. Skokov[3], O. Gutfleisch[3], and J. Wosnitza[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]MAGNOTHERM Solutions GmbH, Darmstadt, Germany — [3]Technical University of Darmstadt, Darmstadt, Germany

Magnetic cooling can be utilized to construct environmentally friendly cooling devices, air conditioners, and heat pumps. Recently, low temperatures became the focus of attention as an area of application for magnetocaloric cooling, namely for hydrogen liquefaction. The conventional liquefaction process uses up to 40 % of the lower heating value of the gas we are compressing, just to liquefy it! Magnetocaloric materials enable an alternative and more efficient approach. A large number of compounds are already known that show magnetocaloric effects in the desired temperature range and new candidates are constantly being added. In this work, we would like to discuss our current progress for the creation of a materials library for cryogenic applications. The basis for this is our characterization infrastructure for materials research at TU Darmstadt and the Dresden High Magnetic Field Laboratory in static and pulsed magnetic fields. Furthermore, we also provide an overview of the recent results in the demonstrator development of a magnetic hydrogen liquefier within the framework of the European project HyLICAL.

TT 30.2 Tue 10:00 POT/0151

Hydrogen tunned transition temperature of GdFeSi for magnetocaloric hydrogen liquefaction application — •Allan Döring[1], Wei Liu[1], Marc Strassheim[2], Tino Gottschall[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Institute of Materials Science, Functional Materials, Technical University of Darmstadt, Darmstadt, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany

Hydrogen can play an important role in the future carbon-neutral society. Among several alternatives to store this energy carrier, the liquid H2 (LH2) stands out for its higher volume-to-energy ratio. However, the actual method of H2 liquefaction sums up to 34% of the costs of LH2. The magnetocaloric cooling could be one alternative to improve the efficiency of the process. Thus, it is essential to conduct research on materials exhibiting a strong magnetocaloric effect (MCE) within the temperature range of 20 K to 77 K. The peak of the MCE is at transition temperatures, such as the Curie temperature (TC). The magnetocaloric effect peak of GdFeSi is at 125 K. In this study, the TC of GdFeSi was shifted to lower temperatures by hydrogenation process, achieving a shift of over 90 K. By the anisotropic crystal expansion, GdFeSiH exhibited and higher magnetocaloric effect than the pristine alloy, not only by the isothermal entropy change, but also directly measured adiabatic temperature change. We acknowledge the HyLICAL project for the funding of this research through grant 101101461, and Deutsche Forschungsgemeinschaft (DFG) within the CRC/TRR 270 (Project-ID 405553726).

TT 30.3 Tue 10:15 POT/0151

First-principles investigation of chemical substitution and interstitial doping in La(Fe,Si)$_{13}$ — •Anita Yadav and Markus E. Gruner — University of Duisburg-Essen, 47057 Duisburg, Germany

La(Fe$_x$Si$_{1-x}$)$_{13}$ is a prominent magnetocaloric material, characterized by a sharp first-order phase transition and a large associated entropy change. Its behavior arises from an intricate coupling among the magnetic, electronic, and lattice degrees of freedom, which makes the material highly responsive to external factors and enables targeted tuning of its magnetocaloric response [1,2]. The operating range can be modified through substitution and interstitial loading, which can alter the local atomic environment and reshape the coupling between structural and magnetic subsystems. In this work, we employ first-principles calculations in the framework of density functional theory (DFT) to systematically screen the impact of chemical substitution and loading of light elements on interstitial sites with respect to structural stability, lattice expansion, magnetic interactions, and thermodynamic behavior. Furthermore, we explore the benefits of machine-learning force-fields based on our DFT results for an efficient modeling of the thermodynamic properties of La(Fe$_x$Si$_{1-x}$)$_{13}$-based compounds. Funding by the DFG via TRR270 (B06) is gratefully acknowledged.

[1] M. E. Gruner *et al.*, Phys. Rev. Lett. **114**, 057202 (2015)
[2] K. P. Skokov *et al.*, Appl. Phys. Rev. **10**, 031408 (2023)

TT 30.4 Tue 10:30 POT/0151

Magnetocaloric Laves phases based on light rare earths: Addressing Criticality — •M. Strassheim[1,2], L. Beyer[3,4], J. Wosnitza[1,2], and T. Gottschall[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research Dresden, Germany — [4]TU Bergakademie Freiberg, Germany

Laves-phase intermetallic compounds based on heavy rare-earth elements have long been recognized for their excellent magnetocaloric performance at low temperatures, making them promising candidates for cryogenic cooling applications. However, the reliance on heavy rare earths poses challenges in terms of cost, availability, and sustainability. In this work, we explore the magnetocaloric properties of the light rare-earth-based Laves phase $CeFe_2$. By the substitution of Al, its unstable ferromagnetism can be disturbed enough to establish an antiferromagnetic phase below 80 K. Using a combination of structural, magnetic, and direct adiabatic temperature change measurements at the Dresden High Field Laboratory, we investigate the potential of this antiferromagnetic state for its potential in magnetocaloric hydrogen liquefaction.

TT 30.5 Tue 10:45 POT/0151

Pressure effect on the magnetocaloric response of RCo$_2$ Laves Phases — •Catalina Salazar-Mejia[1], E. Bykov[1], W. Liu[2], K. Skokov[2], O. Gutfleisch[2], J. Wosnitza[1,3], and T. Gottschall[1] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Institut für Materialwissenschaft, TU Darmstadt, Germany — [3]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

Rare-earth Laves phases are potential candidates for magnetic refrigeration at cryogenic temperatures. They exhibit large magnetocaloric effects and their transition temperatures can be tuned through elemental substitutions. In this work, we investigate the effect of hydrostatic pressure on the magnetism and magnetocaloric effect of RCo$_2$ Laves phases with rare-earth elements R = Tb, Dy, Ho, and Er. In general, we observe that the Curie temperature, T_C, decreases with applied pressure in all alloys. T_C is most sensitive to pressure in TbCo$_2$, with $dT_C/dp \approx -22$ K/GPa, and this value decreases systematically along the series, reaching $dT_C/dp \approx -7.7$ K/GPa in ErCo$_2$. More interestingly, hydrostatic pressure has an almost negligible effect on the magnetocaloric response - specifically on the isothermal entropy change, ΔS_T, with the exception of HoCo$_2$, where ΔS_T increases by about 26% under an applied pressure of approximately 1 GPa and for a magnetic field change of 5 T.

TT 30.6 Tue 11:00 POT/0151

Manipulating Magnetocaloric Properties Through Magnetic Exchange at Mn$_{3-x}$GaC/Fe Interfaces — •Ivan Tarasov and Ulf Wiedwald — Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Magnetocaloric materials enable solid-state cooling by exploiting temperature changes under magnetic-field variation. Manganese-based antiperovskites (APVs, Mn_3AX) are promising materials due to their sharp, tunable first-order magnetostructural transition (FOMST). A key challenge is to control the working temperature window and enhance the magnetocaloric response within a given material system. Tailoring magnetic exchange interactions offers a new strategy.

Here, we investigate APV/Fe bilayers, focusing on interface-driven exchange effects. Uncoupled $Mn_2GaC_{1.1}$ films show a sharp FOMST at 189 K with a strong $\partial M/\partial T$ peak. A 5 nm Fe cap lowers the transition to 175 K, broadens hysteresis, and suppresses the $\partial M/\partial T$ peak above 1 T. The bare APV exhibits $\Delta S_m \approx 10$ J kg^{-1} K^{-1} at $B = 6$ T, whereas coupling reduces this to ~ 1 J kg^{-1} K^{-1} at $B = 5$ T. In multi-domain bilayers, $\partial M/\partial T$ increases by 15% (AFM–FM) and 46% (FM–PM) for a Fe film thickness of $t = 2.6$ nm, but disappears for $t = 21$ nm, accompanied by an anomaly near 50 K linked to interfacial

AFM ordering.

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TT 30.7 Tue 11:15 POT/0151

Frustration and Antiferromagnetic Ordering in Low-Temperature Materials for Adiabatic Demagnetization — •Anton Jesche, Tim Treu, Marvin Klinger, Jorginho Villar Guerrero, and Philipp Gegenwart — EP VI, Institute of Physics, University of Augsburg, Germany

The development of improved materials for adiabatic demagnetization refrigeration (ADR) has been driven increasingly by research on magnetically frustrated systems, where competing interactions can suppress magnetic ordering to very low temperatures [1]. Such behavior is particularly attractive for low-temperature cooling and has led to several promising rare-earth-based compounds. Notable examples include $KBaYb(BO_3)_2$, which reaches temperatures near 20 mK [2], and $NaGdP_2O_7$, which demonstrates extended hold times below 2 K in standard cryogenic environments [3].

This contribution will highlight selected Yb- and Gd-based materials and discuss the influence of frustration and antiferromagnetic (AFM) ordering on their cooling performance. Using $NaGdP_2O_7$ as a representative case, we examine how magnetic entropy near AFM transitions affects ADR behavior under varying magnetic fields and temperatures. We further show that high-resolution thermodynamic information, such as heat capacity, can be extracted directly from ADR curves.

[1] M. E. Zhitomirsky, Phys. Rev. B, 2003, 67, 104421, [2] Y. Tokiwa, Commun. Mater. 2021, 2, 42, [3] P. Telang, Phys. Rev. B, 2025, 111, 064434